The life and times of *Macomona liliana*, from humble bivalve to fuel for intercontinental flights and provider of ecosystem services

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Introduction

• I want to use some of the research conducted on this sediment dwelling bivalve to illustrate some important issues related to biology, ecology and ecosystem function.

• I want you to think about the implications of what the animal does to the design of field experiments

• And I want you to think about how sediment dwelling organisms interact with their physical and chemical environment
Introduction to soft-bottom habitats

70% of the earth's surface is covered by seawater – mostly of the seafloor is soft-sediment

Not just sand and mud – but hugely diverse habitats – especially in estuaries-continental shelves

These habitats are functionally important and deliver many important good and services

Soft-sediments are diverse in terms of species and habitats and physical and chemical conditions
Coastal ecosystems are the melting pot where terrestrial and marine influences interact - our most multi-use ecosystems.
Basic biology – know your animal

*Macomona liliana*
- Found in estuaries and sheltered coastal waters throughout NZ
- Mainly on intertidal sand flats
- Surface deposit feeder,
- juveniles live in top 2 cm, adults live deeper,
- adults >30 mm in size
• Important food resource for many species
• Strong influences on community and ecosystem dynamics
Fig. 2. Frequency (%) histograms of the size-class structure of *Macomona* and *Austrovenus*, calculated from the combined dataset of all 6 transects.
Juvenile dispersal

- Unlike the rocky shore, many soft-sediments undergo post-larval dispersal.

- For *Macomona* this involves both active and passive transport.

Juvenile dispersal

Tracking marked bivalves shows that juveniles (<1mm) can move over scales of meters in one tidal cycle

Modelling the decay in abundance of marked individuals from 0.25 m² plots shows 50% of the individuals were lost from the experimental plot within the first 17.4 hrs

How might this influence our estimates of density and population structure?

How do you think this might influence the results of field experiments?

Why do they move?

Changes in populations over time – insights into climate change

Variation in the abundance of wedge shells in Manukau Harbour

Is there only one process driving the pattern your interested in?

Abundance (log-scale) of wedge shells at Clarkes Beach, importance of ENSO

ENSO \quad R^2 = 0.28
Abundance (log-scale) of wedge shells at Clarkes Beach, importance of ENSO plus local environmental drivers

ENS0 + site-scale environmental factors
(turbidity, mean wind exposure over the previous month, average Water temp)
Abundance (log-scale) of wedge shells at Clarkes Beach, importance of ENSO plus local environmental drivers plus meta-population dynamics

$R^2 = 0.62$

ENSO + small-scale environmental + biotic (\textit{Macomona} density at Auckland Airport lagged by two months)
Impact of predators

Fig. 13.17 Some marine benthic carnivores. (a) Gastropod *Nassellia*, which uses a specialized radula and buccal mass to drill holes in barnacles and bivalve mollusks; (b) bivalve mollusk *Crepidula*, which uses a pumping siphon to suck up small prey; (c) polychaete *Oligochaeta*, which has a proboscis armed with hooks, used in seizing and tearing prey; (d) decapod crab *Callinectes sapidus*, whose strong claw can crush mollusks; (e) the oyster catcher, *Haematopus ostralegus*, a predator on intertidal bivalve mollusks.

www.teara.govt.nz

www.encountersnorth.org

Phil Battley, UoM
An important feature of this experiment was that we were able to fit our sampling times into periods relevant not only to the density of the two types of predator, but also to seasonal changes in prey density associated with recruitment. Eagle rays are only present on the sandflat during the summer and disturb large volumes of sediment when extracting prey, whereas shorebirds are found on the sandflats throughout the year and feed by removing individual prey items.
After 6 months of predator exclusion, when rays had been absent from the site for several months and *Macomona liliana* had recently recruited.

After 14 months of predator exclusion, when ray predation was at its peak and the density of juvenile *Macomona* was low.
Shorebirds were the major predator on the sandflat prior to this sampling and they are very size-selective feeders. Significant negative effects were apparent on *Macomona liliana* (> 8 mm shell length) and the increasing densities of smaller individuals and species in the exclusion plots were attributed to negative interactions with large *Macomona*.

**Table 3. Results of tests for treatment effects on small and large size classes of *Macomona liliana* and *Austrovenus stutchburyi* sampled 6 mo after initiation of the experiment.**

<table>
<thead>
<tr>
<th>Taxon and size class</th>
<th>p level</th>
<th>Result$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. liliana</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 4 mm</td>
<td>0.0077</td>
<td>S R &gt; B</td>
</tr>
<tr>
<td>&gt; 8 mm</td>
<td>0.0004</td>
<td>B S R</td>
</tr>
</tbody>
</table>

ns: not significant

**Table 5. Results of tests for treatment effects on small and large size classes of *Macomona liliana* and *Austrovenus stutchburyi* sampled 14 mo after initiation of the experiment.**

<table>
<thead>
<tr>
<th>Taxon and size class</th>
<th>p level</th>
<th>Result$^a$</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>M. liliana</em></td>
<td></td>
<td></td>
</tr>
<tr>
<td>&lt; 4 mm</td>
<td>ns</td>
<td></td>
</tr>
<tr>
<td>&gt; 8 mm</td>
<td>0.0001</td>
<td>S &gt; B &gt; R</td>
</tr>
</tbody>
</table>

ns: not significant
Adult infauna as facilitators of colonization on intertidal sandflats

Scaling of adult juvenile interactions

Slopes are very different for relationship between treatment density and juvenile density at different sites and harbours – why?

<table>
<thead>
<tr>
<th>Harbor</th>
<th>Site</th>
<th>Slope</th>
<th>r²</th>
<th>P</th>
<th>Slope</th>
<th>r²</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Manukau</td>
<td>1</td>
<td>-5.771</td>
<td>0.19</td>
<td>0.035</td>
<td>-1.168</td>
<td>0.277</td>
<td>0.0337</td>
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<tr>
<td></td>
<td>2</td>
<td>-0.542</td>
<td>0.02</td>
<td>0.261</td>
<td>-0.269</td>
<td>0.082</td>
<td>0.2197</td>
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<tr>
<td></td>
<td>3</td>
<td>-0.633</td>
<td>0.12</td>
<td>0.080</td>
<td>-0.146</td>
<td>0.085</td>
<td>0.767</td>
</tr>
<tr>
<td>Tauranga</td>
<td>1</td>
<td>-0.305</td>
<td>0.03</td>
<td>0.218</td>
<td>0</td>
<td></td>
<td></td>
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<tr>
<td></td>
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<td>-0.566</td>
<td>0.07</td>
<td>0.145</td>
<td>0.121</td>
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<tr>
<td></td>
<td>3</td>
<td>0.530</td>
<td>0.05</td>
<td>0.184</td>
<td>0</td>
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<tr>
<td>Whangapoua</td>
<td>1</td>
<td>0.015</td>
<td>0.04</td>
<td>0.678</td>
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<td>0.020</td>
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<td>0.595</td>
<td>-0.485</td>
<td>0.156</td>
<td>0.0509</td>
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</tbody>
</table>
What drives ecosystem function in soft-sediments?

– the physical, chemical, and biological processes or attributes that contribute to the self-maintenance of the ecosystem

A network of interactions
Animals have specific effects related to the way they function and often these effects are influenced by interactions between species traits and environmental gradients.
Contrary to our predictions, a decrease in microphyte standing stock was observed with the removal of large deposit feeders, as indicated by decreased chlorophyll a concentration and reduced oxygen efflux in the light. These results imply that the role of large deposit feeders in enhancing nutrient supply to microphytes outstrips their role as grazers. How?

A Clue: In the dark NH₄-N efflux was higher by about 55% when large deposit feeders were present
Bioturbation creates heterogeneous and dynamic geochemical conditions in sediments

Video from Nels Volkenborn
Do changes in coastal ecosystems matter?

• YES!
• Loss of ecosystem services, biodiversity
• The current threat is that organisms may become functionally extinct - We risk losing important ecological processes including resilience
• If we stuff it up too much recovery will be very hard
Loss of ecological resilience and regime shifts – The implications are significant!

Multiple stressor effects

Unfortunate consequences:
- Loss of function
- Homogenisation of communities and ecosystems
- Loss in food web complexity
- Loss of biogenic habitat structure,
- Decreases in the size of organisms
- Slow recovery to previous state

High SSC and SAR

Nutrient enrichments

Changes in Hydrodynamics

Large Bioturbating Fauna

Microphytobenthos

Sediment

Ecosystem responses?
Structured Equation Modelling allows us to integrate causal and exploratory techniques: Can we experimentally manipulate a natural system to....

• Demonstrate changes in interaction networks and the loss of positive feedbacks
• Predict major shifts in ecosystem function?
• Focus future experiments in terms of treatments and gradients?
Positive feedbacks in ecosystem function relationships

Large bioturbators → Microphytes → Muddiness

Nutrient regeneration outpaces grazing in our (so far) non-eutrophic systems

MPB makes sediment sticky

Bioturbators enhance erosion of fines (at some densities)

Sandy sediment bioturbators do not like mud

But the interaction network can change


Specifically: (1) There is a direct negative effect of the large deposit feeding *Macomona* on Microphytobenthos (MPB; represented as chlorophyll \(a\)) due to grazing (Lelieveld et al. 2003). MPB are an important food source for *Macomona*, but there is also exists a positive relationship between chlorophyll \(a\) biomass and *Macomona* density (Thrush et al. 2006). Similarly, (2) sediment organic content increases the food resources for *Macomona* (by analogy to the functionally similar species *Macoma balthica*, Peterson and Skilleter 1994). (3) MPB are highly productive (Cahoon 1999) and rely on nutrients remineralise in sediments to sustain that production (Lohrer et al. 2004). *Macomona* affect pore water nutrient concentrations directly through (4) and indirectly (2 & 5) through influencing organic matter pools via grazing and behaviorally induced pressure gradients in permeable sediments (Volkenborn et al. 2012, Woodin et al. 2012). (6) *Austrovenus* has a positive effect on chlorophyll \(a\) (Thrush et al. 2006), although these effects are density dependent (Sandwell et al. 2009, Lohrer et al. 2011). (7) interactions between large *Macomona* and *Austrovenus* have been specifically identified (Thrush et al. 1996). (8 & 9) The density of both bivalves species are negatively impacted by mud (Thrush et al. 2003, Thrush et al. 2004), but high densities of both species can winnow fines via bioturbation enhancing erosion (Thrush et al. 1996, Jones et al. 2011). (10) In coarse sediments *Austrovenus* density increases (Thrush et al. 2008). (11) A positive relationship between benthic chlorophyll \(a\) and sediment muddiness exists (Van de Koppel et al. 2001) due to fine sediment binding by MBP, a relationship (8 & 9) mediated by resident macrofauna (Van Colen et al. 2013). (12) Mud and sediment organic content are tightly correlated (Sloth et al. 1995) and (13) coarse sediments influence sediment organic content by increasing permeability and accelerating decay rates (Huettel and Rusch 2000). Degrading chlorophyll \(a\) (14) also contributes to the pool of organic matter in the sediment (Ehrenhauss et al. 2004) and (5), the concentration of porewater nutrients is positively correlated with the sediment organic content through microbial degradation processes (Sloth et al. 1995, Grabowski et al. 2011).
The experiment
Conceptual diagram of the potential interaction network linking infaunal bivalves to benthic chlorophyll a and sediment characteristics.

If the intrinsic dynamics change we should see:

Loss of positive feedback
One hundred days later........................

Unshaded

χ² (P = 0.269); RMSEA (P = 0.494); CFI = 0.989

Shaded

χ² (P = 0.942); RMSEA (P = 0.962); CFI = 1.000

Unstressed is more positively connected
A summary

• We have discussed how the population structure of *Macomona* is influenced by different physical and biological process and how these processes interact.

• We have talked about how experimental results can vary from place to place and how this leads to new insights and greater generality in our understand

• We have also talked about how these animals affect ecosystem function and what the consequences of changes in the performance of these animals may mean to the flux of energy and matter
Selected reading


